An evaluation of PHYTOPHTHORA ROOT ROT of PORT-ORFORD-CEDAR in CALIFORNIA

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ABSTRACT

The Port-Orford-cedar stands on Federal, State, and private lands in northern California were surveyed in the spring of 1980 for the presence of Phytophthora root rot, caused by Phytophthora lateralis. Specific stand and individual tree data were taken at 50 sites. Other areas were inspected for dead or dying cedar on the ground and by use of optical bar photography. The disease was present at six sites on the Gasquet Ranger District, Six Rivers National Forest, Del Norte County, at Jedediah Smith Redwoods State Park, Del Norte County, and on ornamental cedar at one site in the city of Eureka, Humboldt County. The disease was not detected in other areas. Available management options for reducing the risk of spread of the disease to uninfested areas are presented.

INTRODUCTION

Phytophthora root rot, caused by Phytophthora lateralis Tucker & Milbrath, is a fatal disease which is threatening the existence of Port-Orford-cedar, Chamaecyparis lawsoniana (A. Murr.) Parl. throughout its native range. Port-Orford-cedar has a limited distribution (Fig. 1), growing along the Pacific Coast from near Coos Bay, Oregon to the Mad River drainage in Humboldt County, California, 220 miles south. In California, the tree continues eastward through the redwood, Douglas-fir, and mixed conifer forests with the eastern limit of the main distribution near Indian Creek north of Happy Camp. The species reappears further inland on the upper Trinity and Sacramento River systems, predominantly on serpentine soils. It is common, but not conspicuous, on the west side of the Sacramento River canyon from Scott Camp Creek south to Shotgun Creek (2). It is widely planted as an ornamental in the Pacific Coast states.

Most of the Port-Orford-cedar harvested is exported to Japan where the wood has religious significance and is used in shrines and temples (3). In Oregon, the price of Port-Orford-cedar increased from $5.00/MBF in 1921 to more than $1000/MBF in 1976. Present prices in coastal northern California average $2500 to $3000/MBF, making it economical to salvage any dead cedar. The estimated volume of Port-Orford-cedar in California is 240 million board feet.

Root rot of Port-Orford-cedar was first reported in the United States near Seattle in 1923 on nursery stock imported from France (6). The causal fungus was identified and named Phytophthora lateralis in 1942 (13). In 1952 the disease was found at three locations in the cedar's native range in southwestern Oregon and within two years was widely distributed throughout its native range in that State (6). By 1970 the disease had spread to the limits of the cedar range in the lowlands, but its spread into the mountain forests has been slower. The disease has been reported on Port-Orford-cedar in its native range in Oregon, and on other species of Chamaecyparis used as ornamentals and planting stock in the states of Oregon, Washington, and in British Columbia (1). The disease has not been previously reported in California.

In the forest, the soil-borne fungus attacks only Port-Orford-cedar. Young feeder roots are infected first. The fungus then spreads into the inner bark of the main trunk to quickly kill the tree. A sharp line of demarcation between the white color of the live cambium and phloem and the cinnamon to dark brown color of the dead tissue is evident at the root collar (Fig. 2). As the fungus begins girdling the trunk at the soil line, the foliage throughout the crown turns yellow, then bronze, then light brown (Fig. 3) (6). Attack of weakened, dying trees by cedar bark beetles (Phloeosinus spp.) may occur (7).

The objectives of this survey were to 1) determine if P. lateralis was present on Port-Orford-cedar in California, and, if it was present, to 2) determine its distribution and impact, and to 3) formulate management options.

In this evaluation, survey results are summarized, the biology of P. lateralis is discussed, and management options are given.

FIGURE 1. The natural range of Port-Orford-cedar, Chamaecyparis lawsoniana. (Map from Henley, 1973).

FIGURE 2. Discoloration of inner bark at the root collar of Port-Orford-cedar, resulting from infection by Phytophthora lateralis.

FIGURE 3. Crown symptoms on Port-Orford-cedar trees infected with Phytophthora lateralis.

SURVEY METHODS

Concentrations of Port-Orford-cedar on the Six Rivers, Klamath and Shasta-Trinity National Forests were mapped by Forest personnel and located by us. Cedar in State parks and on private lands were also surveyed. When appropriate, the following information was recorded:

1. Stand class (species present, dbh class, and percent crown closure).

2. Site data, including topography (ridge top; upper, mid or lower slope; flat; or stream bottom), aspect, percent slope, proximity to standing or running water, and proximity to roads.

3. Individual tree data (height, dbh, crown symptoms).

4. Insect and disease data (presence or absence of discoloration in inner bark, presence or absence of cedar bark beetles).

Data were recorded at 50 sites which were examined in the spring and early summer of 1980. Detailed information was recorded on these sites because of the presence of dead cedar, the site's representation of an entire area, or because of the site's location (isolated stand, potential research natural area, etc.).

Other Port-Orford-cedar in drainages and draws noted during the field survey were examined, but stand and/or individual tree data were not recorded at these areas because dead cedar, fading crowns, or discoloration of cambial tissue at the root collar region were not present. Other, more inaccessible, areas were examined for fading crowns of Port-Orford-cedar by the use of optical bar photography flown in September, 1979.

Final diagnosis for the presence of *P. lateralis* in trees was done in the laboratory by the following method. Bark and wood tissue collected from margins of discoloration on cedar stems were surface-sterilized in 0.5% sodium hypochlorite, and then placed on either 3% antibiotic medium (4) or on Difco corn meal agar with ampicillin added. These media are selective for species of *Phytophthora* and *Pythium*. Plates were incubated at 20 C. The presence of *P. lateralis* was confirmed by characteristics of the mycelium and spores produced in culture (11, 14). As *P. cinnamomi* Rands can cause similar symptoms on Port-Orford-cedar (8, 9), the presence or absence of other *Phytophthora* spp. was also noted.

RESULTS AND DISCUSSION

Phytophthora root rot was found on Port-Orford-cedar at eight of 50 sites examined in detail and at none of the other sites. Six of the sites were on the Gasquet Ranger District, Six Rivers National Forest, one was at Jedediah Smith Redwoods State Park, and one was in the city of Eureka (Appendix, Table 1). Phytophthora lateralis was the only Phytophthora sp. isolated in culture. Specific observations follow.

GASQUET RD, SIX RIVERS NF

The district includes most of the Smith River drainage system within Del Norte County, and borders on Oregon to the north. Most roads on the district were traveled in the course of the survey. Site data were taken at 12 sites and general notes were taken at others. Phytophthora lateralis was present at six of the 12 sites (Fig. 4).

Four of these sites were along the South Fork of the Smith River. One site with approximately 70 dead and dying cedar was salvaged in June, 1980. Currently fading trees had typical discoloration in the cambial region and heavy infestations of Phloeosinus spp. Two fading cedar at the Rock Creek subdivision site were infected. Numerous other dead or fading cedar, some apparently planted, were present at the same site. Approximately 10 cedar at the Boulder Creek site, 2 miles from the subdivision, were infected. These trees were next to and downslope from the road. The pattern of fading, with dead trees at the road and most recent fading furthest downslope, indicated a recent source of infestation orginating from the road. Two small (3 feet in height) cedar uphill from the South Fork road and a few miles from the Boulder Creek site were infected.

Two other sites on the District were infested. Two cedars, 4 to 5 feet high, with yellow foliage and cambial discoloration, were infected. They were along a drainage crossing the Knopki Creek Road. A block on the upper Myrtle Creek drainage, which was clearcut in the 1960's, had 175 to 200 small (under 10 feet in height) cedar, 50% of which were dead or dying from cedar root rot. Most of these trees were also infested with Phloeosinus spp. The equipment used to clearcut this area came from the Rock Creek subdivision (Niesen, personal communication).

Large Port-Orford-cedars along the Middle Fork of the Smith River, along Highway 199 from South Fork Road to Patrick Creek Road, have been dying since the late 1960's (Wells, personal communication). Most of these cedar were salvaged as they died. No samples were taken from the dead trees remaining. Smith River drainages on the southern part of the District -- including Eightmile Creek, Harrington Creek, South Fork east of Big Flat Station, and Quartz Creek - were not examined on the ground, but no fading cedar were observed on optical bar photography.

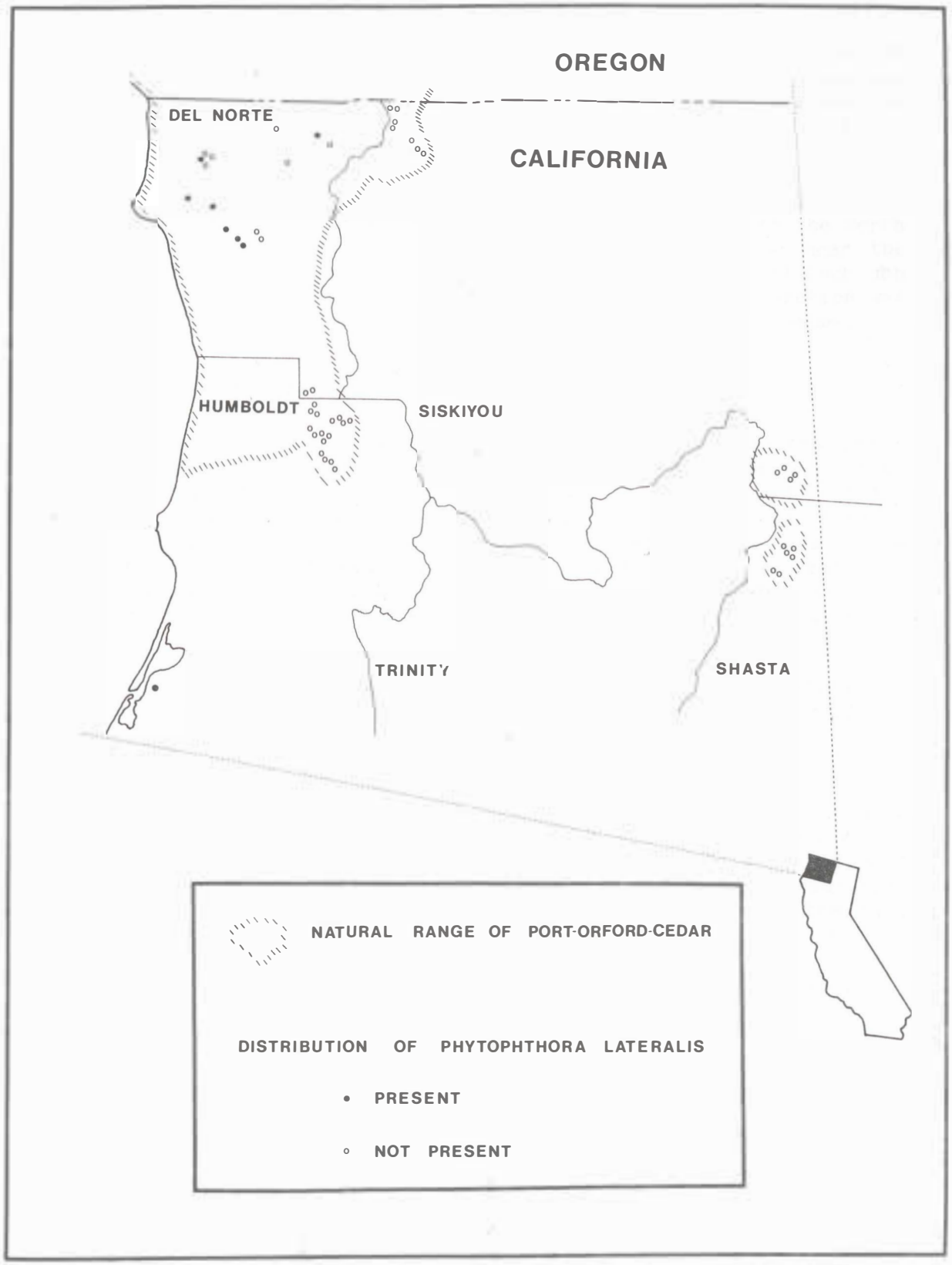

FIGURE 4. Distribution of Phytophthora root rot of Port-Orford-cedar in northern California. The sites were sampled in the spring of 1980.

OTHER AREAS IN DEL NORTE COUNTY

A row of 10 Port-Orford-cedar planted at the entrance to Jedediah Smith Redwoods State Park was infected. The decline of the trees was progressing from one end of the row to the other. Cedar bark beetles were present. Cedar root rot was not observed on natural Port-Orford-cedars in the Park.

Scattered large, dead Port-Orford-cedar trees were present along the main fork of the Smith River from the South Fork junction to the North Boundary of Jedediah Smith Redwoods State Park. One site near the North Bank intersection with three, recently dead, 8 to 10 inch dbh cedars was checked for P. lateralis, but no cambial discoloration was present and the fungus was not isolated from root or stem tissues.

ORLEANS RD, SIX RIVERS NF

The Orleans Ranger District is located within the northwestern portions of the Klamath River drainage system, in parts of Del Norte, Humboldt, and Siskiyou counties. The District contains some of the largest stands of sawtimber-size Port-Orford-cedar in California, including a 1/4-section area near Aikens Creek which is a proposed Port-Orford-cedar Research Natural Area, and stands at and near Blue Lake. Introduction of P. lateralis into these areas, as well as other areas on the District, would result in considerable loss of high value timber.

Specific site data and tissue samples were taken at 18 sites and general notes were taken at others. Cedar root rot was not found at any of these sites.

Though the root pathogen is apparently absent from the Orleans District, it was present in the city of Eureka, Humboldt County, approximately 70 miles southwest of the Orleans District along the coast. Six cedars, which were transplanted as seedlings from near Coos Bay, Oregon in 1949 or 1950, had external symptoms of cedar root rot. The fungus was isolated from discolored tissues at the root crowns. The fungus could have been carried with the seedlings or, more likely, was probably recently introduced from some vehicle passing though or parked in the alley directly behind the trees.

KLAMATH NF

Site data were recorded at seven sites on the Happy Camp Ranger District, Siskiyou County, including a 20-to-30 acre stand on the Louse Creek drainage and a 10-acre stand south of Granite Creek drainage designated by the District as a Port-Orford-cedar Management Area. Cedar root rot was not found. Many of the concentrations of Port-Orford-cedar are on or near the Little Grayback road, which is a main, and much traveled, route for logging trucks between southern Oregon and northern California.

SHASTA-TRINITY NF

Site data were taken at six sites on the Mt. Shasta Ranger District in Shasta County (two in the Boulder Creek area, four in the Sims Station area), and four sites in Siskiyou County (two along the Sacramento River, and two in the Castle Lake Road area along Scott Camp Creek). One site in Trinity County (Scott Mountain Campground) was checked. Cedar root rot was not found.

Most Port-Orford-cedars on the Shasta-Trinity National Forest are in more isolated and higher elevation areas than those growing nearer the Pacific coast. The cedar on the Shasta-Trinity, such as those near the Methodist Church Camp, have aesthetic value as well as scientific value as the eastern limits of the species range.

BIOLOGY OF PHYTOPHTHORA LATERALIS

Phytophthora lateralis is a soil-invading, root-inhabiting fungus that infects succulent Port-Orford-cedar roots, kills the roots and girdles the tree at the root collar. The fungus forms sac-like reproductive structures (sporangia) which release motile zoospores under favorable soil temperature (10-20 C) and high soil moisture conditions (11). Zoospores can be spread locally in free soil water and over longer distances in surface water. Permeation of surface water containing zoospores into the soil can result in infection of root tips. When zoospores reach susceptible root tips, they germinate, penetrate host roots, and initiate infection. Occasional infection of foliage can occur when low-hanging branches brush against infested soil during wet, windy weather (12).

The fungus also forms thick-walled resting spores (chlamydospores) in soil organic matter and in host roots (5, 10). Chlamydospores germinate in saturated, cool soil and then form sporangia which release zoospores to initiate new infections. If soils infested with chlamydospores are carried to uninfested areas, either by water or other agents, new infections can occur.

The chlamydospores are resistant structures which can survive in the soil during dry, warm weather when conditions are unfavorable for growth of the fungus. Ideal conditions for growth of the fungus and spread of the disease are thus during the cool, wet late winter and early spring months (10, 11).

Because the fungus is soil-borne, produces motile spores, and does not form spores above ground, the distribution of the disease is associated with water drainages, surface water movement, and with movement of infested soil. In Oregon, spread of the disease over long distances occurred through movement of infected planting stock, and through movement of infested soil during construction, forest road maintenance and use, and logging operations (6). Initiation of many new disease centers thus occurred along roads where logging and road building activities took place. Infested soil can also be carried by cattle or wild game. Once the fungus is moved to a new area, local spread by water drainages becomes important in buildup of the disease and spread downslope. The fungus will not survive in the soil for more than a year or so in the absence of the host.

MANAGEMENT OPTIONS

This survey indicated that a substantial portion of the Port-Orford-cedar sites on the Gasquet District are contaminated with P. lateralis. The infestation in Eureka was likely the result of movement of cedar stock or soil from infested areas. Currently infected stands are lost; there is no known method of eliminating the fungus from an area already contaminated. Port-Orford-cedar may continue to regenerate in these areas, but they will not reach merchantable size. Nevertheless, there are considerable areas of Port-Orford-cedar in California which are, at present, free of the disease, and management options are available to protect the economic, scientific and aesthetic value they represent.

1. Do Nothing. Mortality in infested areas will continue. The fungus will spread via root contact and zoospores to adjacent cedars and locally downslope in drainage water. Long distance spread to uninfested areas by agents such as contaminated logging equipment is likely. Spread to, and establishment in, uninfested areas will result in death of the cedars. Introduction and establishment of the disease in areas such as the high-volume stands on the Orleans District and the Port-Orford-cedar Management Area on the Happy Camp District will result in considerable economic loss. Spread to areas such as the proposed Port-Orford-cedar Natural Area on the Orleans District, and areas on the Mt. Shasta District at the limits of the natural range of the species, would result in loss of the scientific and aesthetic value the species provides.

2. Salvage Trees as They Die. Volume will be recovered but the rate of additional mortality in surrounding cedars will not be reduced and the risk of local and/or long-distance spread to uncontaminated areas will not be decreased. Salvage with ground disturbance during the wet season will increase the risk of vehicles and equipment becoming contaminated with infested soil and subsequent spread of the disease to other areas. Salvage operations during the drier months and with minimal disturbance, such as the use of helicopter or cable logging, will minimize chances of disease spread.

   Cedar reproduction in these infested areas will become infected and die before reaching merchantable size. The continued presence of susceptible trees will perpetuate the fungus. Removal of all cedar, including the understory, from the infested site, followed by site preparation and planting with a species other than Port-Orford-cedar, will help eliminate the fungus from the soil and reduce chances of spread.

3. Initiate Quarantines to Prevent or Slow Spread. Protection of the Port-Orford-cedar resource in California will require implementation of quarantines to minimize spread of the disease. The disease is spread, or vectored, mainly by the activities of man, such as unnecessary entry into infested stands, transportation of infected cedars, and movement of contaminated vehicles and equipment into areas free of the disease. These activities can be regulated. Although complete exclusion of the pathogen over a period of many years is unlikely, the risk of establishing new infections in disease-free stands can be reduced by regulation. The scope of regulations developed will depend on the objectives of the Federal, State, and private land managers involved.

   Disease spread can be minimized by developing quarantines which would restrict the entry of man into infested areas and/or restrict the entry of contaminated vehicles and equipment into disease-free stands.

   a. Restrict entry into infested areas. Except for isolated ridges, it should probably be assumed that all Port-Orford-cedar sites on the Gasquet District are, or soon will be, infested with P. lateralis. This means that 1) Port-Orford-cedar will not be a commercial species on the District, and 2) entrance of vectors into these areas during the wet spring months will likely result in contamination. Removal of cedar seedlings from the District, or from the tree's natural range in Oregon, for transplanting elsewhere will likely result in spread of the disease. Chances for survival of the fungus in soil or on seedlings carried by vectors are greatest in wet soil and lowest in dry soil.

   b. Restrict entry of contaminated vehicles and equipment into disease-free stands. It should be assumed that vehicles and logging equipment used recently in Port-Orford-cedar sites in Oregon or on the Gasquet District are carriers of the disease. Their movement to uninfested cedar areas will likely result in new infestations. Restricted entry of contaminated equipment into noninfested areas would reduce risk of new infections. Thorough washing of soil from these vehicles and equipment before entry would have the same effect.

      It may not be feasible to restrict entry into all disease-free Port-Orford-cedar sites in California. Rather, efforts could be directed first, to identifying sites of value, such as proposed Research Natural Areas and sites located upslope from roads and drainages, and then to developing regulations designed specifically for protecting these sites. It should be relatively easy to restrict entry into the isolated areas on the Shasta-Trinity which contain Port-Orford-cedar.

The Powers Ranger District on the Siskiyou National Forest in Oregon has attempted to limit spread of the fungus to disease-free cedar production sites by contract restrictions and by development of an educational program. Clauses restricting operations on sale areas to periods of dry weather, not allowing tractor yarding, and requiring the gating of roads to limit travel during the wet season have been included in contracts. Informing the public and those working on the sites as to why restrictions are necessary has proved useful.

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SHASTA-TRINITY NATIONAL FOREST

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APPENDIX

TABLE 1. Descriptions of sites in northern California infested with *Phytophthora lateralis*.

Location	Township	Range	Section	Description
Six Rivers NF,	17 N	1 E	21	Myrtle Creek
Gasquet RD	16 N	2 E	19	South Fork Road, Smith River
	15 N	2 E	5	Rock Creek Subdivision, South Fork Road, Smith River
	15 N	2 E	4	Boulder Creek, South Fork Road
	15 N	2 E	10	South Fork Road
	18 N	4 E	24	Knopki Creek
Jedediah Smith Redwoods State Park	16 N	1 E	8	Park entrance
Eureka	5 N	1 E		Ornamental planting